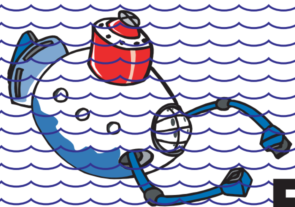

From the Gulf of Mexico to the Moons of Jupiter

Focus

Adaptations to unique or "extreme" environments

Grade Level

9-12 (Earth Science)

Focus Question

What adaptations found in microorganisms living in cold-seep communities in the Gulf of Mexico might also be seen in microorganisms living on other planetary bodies?

Learning Objectives

Students will be able to explain the process of chemosynthesis.

Students will be able to explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps.

Students will be able to compare physical conditions in deep-sea "extreme" environments to conditions thought to exist on selected moons of Jupiter, and discuss the relevance of chemosynthetic processes in cold seep communities to the possibility of life on other planetary bodies.

Additional Information for Teachers of Deaf Students

In addition to the words listed as key words, the following words should be part of the vocabulary list.

Oxidizing
Hydrogen sulfide
Hydrocarbon gases
Seep
Sediment
Continental margins
Methane
Polychaete worms
Phylum
Chemosynthetic bacteria
Hemoglobin
Adaptation
Toxicity
Cyanide
Cytachrome molecule
Metabolism
Photosynthesis
Respiratory membrane
Diffusion membrane
Efficient
Extracting
Exposure
Symbiotic relationship
Simultaneously

There are no formal signs in American Sign Language for any of these words and many are difficult to lipread. Having the vocabulary list on the board as a reference during the lesson will be extremely helpful. It would be very helpful to copy the vocabulary list and hand it out to the students to read after the lesson. The "Me" Connection should be included as homework.

Materials

None

Audio/Visual Materials

None

Teaching Time

One-half 45-minute class period for introduction, plus one-half 45-minute class period for discussion

Seating Arrangement

Classroom style

Maximum Number of Students

32

Key Words

Cold seeps
Methane hydrate ice
Chemosynthesis
Brine pool
Vestimentifera
Trophosome

Background Information

One of the major scientific discoveries of the last 100 years is the presence of extensive deep sea communities that do not depend upon sunlight as their primary source of energy. Instead, these communities derive their energy from chemicals through a process called chemosynthesis (in contrast to photosynthesis in which sunlight is the basic energy source). Some chemosynthetic communities have been found near underwater volcanic hot springs called hydrothermal vents, which usually occur along ridges separating the Earth's tectonic plates. Hydrogen sulfide is abundant in the water erupting from hydrothermal vents, and is used by chemosynthetic bacteria that are the base of the vent community food web. These bacteria obtain energy by oxidizing hydrogen sulfide to sulfur:

$CO_2 + 4H_2S + O_2 > CH_2O + 4S + 3H_2O$

(carbon dioxide plus hydrogen sulfide plus oxygen yields organic matter, sulfur, and water). Visit http://www.pmel.noaa.gov/vents/home.html for more information and activities on hydrothermal vent communities.

Other deep-sea chemosynthetic communities are found in areas where hydrocarbon gases (often methane and hydrogen sulfide) and oil seep out of sediments. These areas, known as cold seeps, are commonly found along continental margins, and (like hydrothermal vents) are home to many species of organisms that have not been found anywhere else on Earth. Typical features of communities that have been studied so far include mounds of frozen crystals of methane and water called methane hydrate ice, that are home to polychaete worms. Brine pools, containing water four times saltier than normal seawater, have also been found. Researchers often find dead fish floating in the brine pool, apparently killed by the high salinity.

Where hydrogen sulfide is present, large tubeworms (phylum Pogonophora) known as vestimentiferans are often found, sometimes growing in clusters of millions of individuals. These unusual animals do not have a mouth, stomach, or gut. Instead, they have a large organ called a trophosome, that contains chemosynthetic bacteria. Vestimentiferans have tentacles that extend into the water. The tentacles are bright red due to the presence of hemoglobin which transports hydrogen sulfide and oxygen to bacteria in the trophosome. The bacteria produce organic molecules that provide nutrition to the tube worm. A similar symbiotic relationship is found in clams and mussels that have chemosynthetic bacteria living in their gills. Bacteria are also found living independently from other organisms in large bacterial mats A variety of other organisms are also found in cold seep communities, and probably use tubeworms, mussels, and bacterial mats as sources of food. These include snails, eels, sea stars, crabs, lobsters, isopods, sea cucumbers, and fishes. Specific relationships between these organisms have not been well-studied.

The Gulf of Mexico contains the largest reservoir of fossil fuel in the continental U.S., and the geology of the area has been intensively studied for more than 50 years. While cold seep communities were discovered in the Gulf more than 20 years ago, the biology of these communities has been studied at only three sites less than 20 km apart. Exploring for new cold seep sites and studying the biology and ecology of the organisms that live there is the focus of the Ocean Exploration 2002 Gulf of Mexico Expedition. Special attention is being paid to the ecology of microorganisms that live in the brine pools and methane hydrates associated with cold-seep communities. The discovery that these organisms thrive in conditions that are normally considered unsuitable for life has challenged many commonly held assumptions about the limits to life on Earth. These organisms also have intriguing implications for recent explorations of other parts of our solar system.

This activity focuses on life in "extreme" environments, and on what our knowledge of cold-seep communities may suggest about the possibility of life on other planetary bodies.

Learning Procedure

1. Lead a discussion of deep-sea chemosynthetic communities. Contrast chemosynthesis with photosynthesis, and be sure students understand that there are a variety of chemical reactions that can provide this kind of energy. Contrast hydrothermal vent communities with cold-seep communities. Visit http://www.bio.psu.edu/cold_seeps and http://www.bio.psu.edu/hotvents for virtual tours of cold seep and hydrothermal vent communities. Point out that until recently it was well-accepted that photosynthesis was the basis of all major biological communities on Earth. Recognition of these communities has changed this view dramatically; indeed, many biologists now favor the idea that life on Earth may have begun in chemosynthetic communities like those found near hydrothermal vents and cold seeps. Tell students that their assignment is to relate what is known about these communities on Earth to our knowledge of conditions on the moons of Jupiter. They may reach whatever conclusion they feel is supported by available evidence, and should include the following in their considerations:
   - DNA of Archea
   - Core material of Jupiter's moons
   - Considering that Jupiter's moons are quite a bit farther from the sun, would not temperatures be far below those of even the coldest places on Earth?
   - Is there any evidence of volcanic activity on any of Jupiter's moons that might create hydrothermal vents?
   - Is there any evidence that water exists on any of these moons?
   - What chemosynthetic reactions known to occur in deep sea communities might also occur on one or more of Jupiter's moons?

The websites listed under "Resources" may be helpful for this assignment.

2. Lead a discussion of the relevance of cold seep chemosynthetic communities to the possibility of life on Jupiter's moons. Students should recognize that Europa appears to have a substantial amount of water, and may have a liquid ocean underneath the surface ice layer. Hydrates have also been found on Europa, and sulfur-containing compounds are abundant on Io. Articles in the January-February, 2002 issue of the *American Scientist* and the October, 1999 and February, 2000 issues of *Scientific American* have a more in-depth discussion about possible ocean habitats on Europa and the Galileo mission (you may choose to point your students toward these articles, or find out if they will discover them on their own!).

The BRIDGE Connection

www.vims.edu/bridge/vents.html and www.vims.edu/bridge/geology.html

The "Me" Connection

Have students write a short essay on why the decision to cancel funding for the Europa orbiter was or was not a good idea, and in what way this decision might affect them personally.

Connections to Other Subjects

English/Language Arts, Biology, Chemistry

Evaluation

Written reports may be scored according to a rubric based on points identified in Step #2. Thoroughness of research (e.g., inclusion of references not provided by the instructor) may be added to this rubric if desired.

Extensions

Have students report on other "extreme" environments under study with support from the National Science Foundation's LExEn (Life in Extreme Environments) program.

Resources

http://oceanexplorer.noaa.gov – Follow the Gulf of Mexico Expedition daily as documentaries and discoveries are posted each day for your classroom use.

http://www.bio.psu.edu/People/Faculty?Fisher/thome.htm – Web site for the principal investigator on the Gulf of Mexico expedition

http://www.rps.psu.edu/deep/ – Notes from another expedition exploring deep-sea communities

http://www.ridge.oce.orst.edu/links/edlinks.html – Links to other deep ocean exploration web sites

http://www-ocean.tamu.edu/education/oceanworld/resources/ – Links to other ocean-related web sites

http://www.jpl.nasa.gov/europaorbiter/ – Information on Europa and the Europa orbiter project

http://www.jpl.nasa.gov/galileo/gem/ – Information on the Galileo outer planets exploratory program

Paull, C.K., B. Hecker, C. Commeau, R.P. Feeman-Lynde, C. Nuemann, W.P. Corso, G. Golubic, J. Hook, E. Sikes, and J. Curray. 1984. Biological communities at Florida Escarpment resemble hydrothermal vent communities. Science 226:965-967 – early report on cold seep communities.

National Science Education Standards

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard B: Physical Science

- Chemical reactions
- Interactions of energy and matter

Content Standard D: Earth and Space Science

- Energy in the Earth system
- Origin and evolution of the Earth system

Activity developed by Mel Goodwin, PhD,
The Harmony Project, Charleston, SC

Notes/Thoughts/Inspirations